Polymer Testing 60 (2017) 110–116

Contents lists available at ScienceDirect

Polymer Testing

journal homepage: www.elsevier.com/locate/polytest

Material Properties

Tensile and flexural properties of polypropylene composites filled with highly effective flame retardant magnesium hydroxide

Ji-Zhao Liang

Research Division of Green Function Materials and Equipment, School of Mechanical and Automotive Engineering, South China University of Technology, Guangzhou 510640, PR China

ARTICLE INFO

Article history:
Received 8 February 2017
Accepted 13 March 2017
Available online 18 March 2017

Keywords:
Polymer-matrix composites
Mechanical properties
Stress/strain curves
Strength
Elastic properties

ABSTRACT

The reinforcing effects of highly effective flame retardant magnesium hydroxide (FMX) content on the tensile and flexural properties of filled polypropylene (PP) composites were investigated within the FMX weight fraction range from 5 to 60 wt%. It was found that the Young's modulus and flexural modulus increased approximately linearly while the tensile yield strength and tensile fracture strength decreased slightly with increasing the FMX weight fraction. When the FMX weight fraction was lower than 20%, the tensile elongation at break decreased considerably, and then decreased slightly; the flexural strength increased when the FMX weight fraction was lower than 30%, and then decreased slightly. The tensile properties increased with increasing rate of tension. Moreover, the tensile yield strength of the composites was estimated using an equation proposed in previous work, and good agreement was shown between the predicted and the measured data.

1. Introduction

For flame retardant polymer composites, both retardant and mechanical properties are important. Polypropylene (PP) is one of general thermoplastics used extensively in industry, agriculture and daily life due to the good insulation properties, small dielectric constant, good stress crack resistance and chemical resistance. However, owing to some defects such as poor flammability resistance and relatively low mechanical strength, the applications of PP resin have been limited [1–4]. In order to broaden the scope of application, PP is often loaded with flame retardants to enhance the flame-retarding ability. Recently, extensive attention has been paid to the flame retardant properties of PP [5–7]. Magnesium hydroxide [$Mg(OH)_2$] is one of the flame retardants used extensively in the polymer industry [7–12]. Titelman and Gonen [7] studied the discoloration of PP-based compounds containing magnesium hydroxide, they found that compounding $Mg(OH)_2$ with polymers leads to the formation of various colors ranging from light grey to rather dark beige. Sangcheol [10] researched the flame retardancy and smoke suppression of magnesium hydroxide filled PP composites. The results showed that the flame retardancy developed by magnesium hydroxide could effectively be increased by the additional incorporation of zinc borate and talc.

The flame retardant properties of flame retardant polymer composites can be improved with higher content of metal hydroxide flame retardant such as $Mg(OH)_2$ and aluminum hydroxide [$Al(OH)_3$], but the mechanical properties of the composites are usually weakened in this case, especially tensile strength and flexural strength [13,14]. Liang and Li [13] investigated the effects of $Mg(OH)_2$ content on the impact fracture toughness of PP/$Mg(OH)_2$ composites, the results showed that the V-notched Izod impact strength of the PP/$Mg(OH)_2$ composites increased non-linearly with increasing the filler weight fraction up to 15 wt%, and then decreased slightly. It is, therefore, quite meaningful to develop highly effective flame retardant such that the retardant properties of polymer composites can be significantly improved even in the case of low content of the metal hydroxide flame retardant. Highly effective flame retardant magnesium hydroxide (FMX) is a new type of magnesium hydroxide with better flame retardant effect than that of general $Mg(OH)_2$ [15,16]. However, there have been relatively few studies on the tensile properties and flexural properties of PP/FMX composites. The objectives of this study are to measure the tensile and flexural properties including Young's modulus, tensile strength, flexural modulus and strength of PP/FMX composites, and to investigate the effects of the FMX content and rate of tension on the mechanical properties of these composites, to be beneficial to understand the reinforced mechanisms of the PP/FMX composites.

E-mail address: scutjzl@sohu.com.

http://dx.doi.org/10.1016/j.polymertesting.2017.03.014
0142-9418/

2. Experimental

2.1. Raw materials

The major raw materials were a polypropylene (PP) and a high effective flame retardant magnesium hydroxide (FMX). PP with trade mark CJS-700G was used as the matrix resin, which was supplied by the Guangzhou Petrochemical Works in Guangdong province (Guangzhou, China). The density in the solid state was 910 kg/m^3 and melt flow rate (230 °C, 2.16 kg) was 10 g/10min. The FMX with trade-mark FMX-507 was supplied by the Jinge Fire-Fighting Materials Co., Ltd. (Foshan city, China), with mean diameter of 1.74 μm. The main compositions and basic properties of the FMX are summarized in Table 1.

2.2. Preparation

The FMX particles were compounded with the PP in a high speed mixer, model CH-10DY, supplied by the Beijing plastics machinery factory (Beijing, China), and then the mixtures were melt blended by means of a co-rotating twin-screw extruder in the temperature range from 165 to 180 °C and a screw speed 200 rpm to produce the PP/FMX composites. The extruder model SHJ-26 was supplied by the Nanjing Chengmeng machinery Ltd. Co. (Nanjing, China). The screw diameter was 24.5 mm, and the screw length-diameter ratio was 40. Finally, the extrudate was granulated. The FMX weight fractions were separately 5, 15, 30, 45 and 60 wt%. The granules were dried at 80 °C for 5 h before fabrication of the specimens. The specimens for tensile and flexural tests were molded using a plastics injection machine (model UN120A) supplied by the Yizumi machinery Co. Ltd. (Foshan, China). The specimens for the tensile tests were dumbbells with width and thickness of 10 mm and 4 mm, respectively, while the specimens for the flexural tests were 80 × 10 × 4 mm.

2.3. Instruments and methodology

The tensile tests of the PP/FMX composites were conducted at room temperature by means of a universal materials testing machine (model CMT4104) supplied by the Newsans Co. Ltd. (Shenzhen, China) according to the ISO 527-1-. The cross-head speeds for the tensile test were 10, 50 and 100 mm/min to investigate the influence of the rates of tension on the tensile properties of the composites. The flexural properties of the PP/FMX composites were also measured at room temperature by means of the universal materials testing machine. The flexural tests were conducted according to ISO 180/1A, with a cross-head speed of 2 mm/min. Each group of specimens contained 5 pieces, and the average values of the measured tensile and flexural properties were used in the reported data.

Table 1
Main compositions and basic properties of FMX.

Properties	Values
MgO content (wt.%)	≥64
Specific gravity (g/cm^3)	2.40
Mohs hardness	2.50
Loss of coolant temperature (°C)	340
Thermal weight loss (%)	30 ± 2
PH value	9–11
The white degree (%)	≥93.0
Moisture (%)	≤1.0
The heat absorption at decomposition (kJ/g)	2

3. Results and discussion

3.1. Tensile properties

3.1.1. Tensile stress versus strain curves

Fig. 1 shows the tensile stress versus tensile strain curves of the PP/FMX composites when the rate tension was 10 mm/min. It can be seen that the maximum tensile strength and the tensile strain at break decrease with increasing FMX weight fraction (φ_f). This indicates that the tensile strength and the tensile ductility of the composites are weakened due to loading FMX into the PP resin. Fig. 2 presents the tensile stress versus tensile strain curves of the PP/FMX composites when the rate of tension was 50 mm/min. It can be observed that the values of the maximum tensile strength and the tensile strain at break decrease with increasing the FMX weight fraction, but the values of the maximum tensile strength are somewhat higher than those of the results shown in Fig. 1. Fig. 3 displays the tensile stress versus tensile strain curves of the PP/FMX composites when the rate of tension was 100 mm/min. Similar to the results shown in Figs. 1 and 2, the values of the maximum tensile strength and the tensile strain at break decrease with increasing the FMX weight fraction, but the values of the maximum tensile strength are somewhat higher than those of the results shown in Figs. 1 and 2. This shows that there is a significant influence of the rate of tension on the tensile strength of the PP/FMX composites.

3.1.2. Relationship between Young's modulus and FMX content

Young's modulus is an important parameter for characterizing the stiffness of materials under tensile load. Fig. 4 illustrates the relationship between the Young's modulus of the PP/FMX composites and the FMX weight fraction. It can be seen that Young's modulus increases almost linearly with increasing FMX weight fraction. It is generally believed that the movement of macromolecular chains of polymer matrix is blocked by the inorganic particles, as well as the physical crosslink points between the filler particles and the macromolecular chains of the matrix. In addition, the inclusions play a role of the skeleton in the polymer matrix. Hence the stiffness of the PP/FMX composites is improved, leading to increasing the Young's modulus with increasing the FMX weight fraction. In other words, the blocking effect and the skeleton effect are two of the major reinforcing mechanisms of inorganic particulate-filled polymer composites [17–19]. Moreover, PP is a

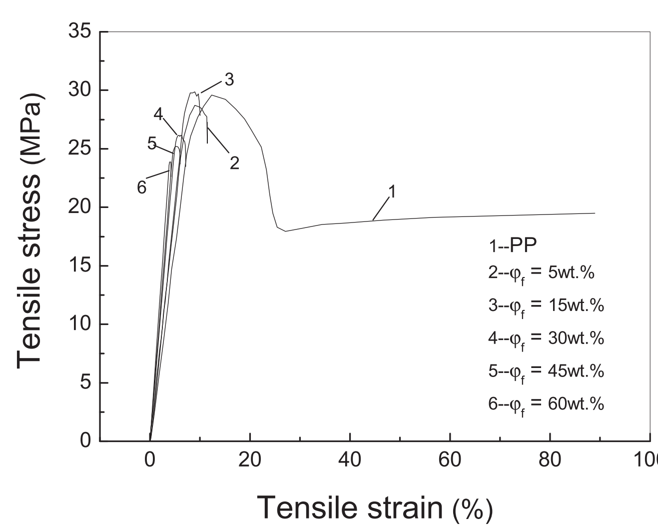

Fig. 1. Tensile stress versus strain curves at rate of tension 10 mm/min.